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ce Preamplifier for Micro-Electrode Studies

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A sub-miniature, solid-state, unity-gain preamplifier suitable for use with both metallic and micropipet micro-electrodes has been developed and has been used to obtain evoked responses from single cells. Records taken show a performance comparable with the best vacuum-tube preamplifiers in current use. It is capable of low-noise operation when used with high source impedances and has an input resistance large compared with the electrode resistance. Since rapid changes in potential are to be recorded, the input capacitance is kept low enough to minimize the filtering effects of the series resistance of the electrode and the shunt capacity of the input circuit.

In the circuit diagram shown, Ql is a field effect transistor employed as a source follower, which provides both a high input resistance and low-noise operation with large electrode resistances.

There remain the problems of reducing the input capacitance and preventing the gate bias resistor R3 from shunting the high resistance of the field effect transistor. Both these problems are solved by bootstrapping, which involves ensuring that if one side of a capacitor or resistor changes in potential the other side experiences a similar change. In this way current flow into the capacitor or resistor is much smaller than it would have been otherwise and the effective capacitance is reduced, while the effective resistance is increased.



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the source of the field effect transistor in order to achieve almost unity gain from gate to source, while transistors Q3 and Q4 form a unity gain non-inverting amplifier with the low output impedance necessary to drive both the drain of Q1 and the gate bias point Vg. Also Q3 has an input impedance high enough to minimize loading of the high collector impedance of Q2. Since the source and drain of Q1 are at virtually the same potential as the gate, both the gate to source and gate to drain capacitances are effectively reduced. Similarly, since the end of the 22-megohm gate bias resistor remote from the gate is also driven at the same potential as the gate, the effective input resistance is much greater than 22 megohms.

The circuit was assembled in a cordwood module, which was placed in a metal container driven at the same potential as the input signal. The resulting package was then covered by, but electrically isolated from, a second box, which was grounded, thus eliminating the effects of stray capacity from the circuit to ground. Because of its small size it was possible to mount the amplifier directly on the micro-manipulator assembly used with the microelectrodes, thereby reducing cable capacity and noise due to inductive and capacitative coupling to the output cable.

The measured performance of the circuit is as follows:

Input resistance 1170 megohms

Input capacitance 0.25 picofarad

Gain 0.98

Frequency response 3 db down at 10 and 98,000 cycles per sec.

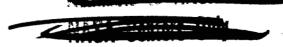
Power required 3 milliwatts

Noise 75 microvolts rms. with a 10 Megohm source

and a 20,000 cps bandwidth

Size  $1.9 \times 1.6 \times 1.6 \text{ cm}$ 

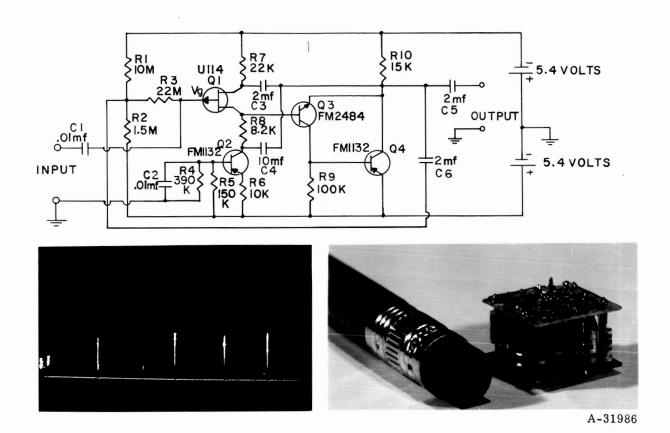
Weight 4.5 gm



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A photograph of the preamplifier and a sample record, an intracellular recording from a vestibular nucleus in a frog during head tilting, are shown in the figure.

In order to further improve the recording of rapidly changing potentials, a preamplifier with a negative input capacitance is being developed.



Micro-electrode field effect preamplifier. Record is an intracellular recording from a vestibular nucleus in a frog during head tilting.